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INSTITUTE FOR ACOUSTICAL RESEARCH
MIAMI DIVISION PALISADES GEOPHYSICAL INSTITUTE

FINAL REPORT

July 1978

BEAR Buoy: Analyses of Acquired

Temperature Data

by

Kenneth L. Echternacht

to

The Office of Naval Research, Code 222
Sensor Systems Program

Contract N00014-74-C-0229

IAR 78001

Miami, Florida 33130

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Institute for Acoustical Research
Miami Division of
Palisades Geophysical Institute

Final Report
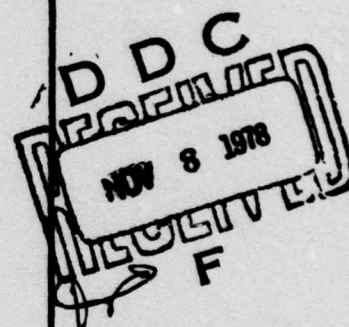
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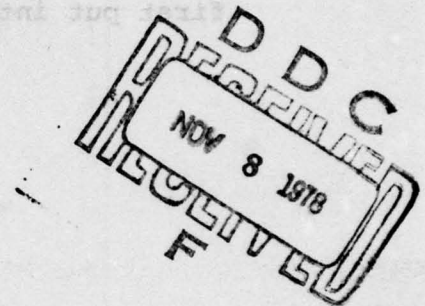
Contract: N00014-74-C-0229   14 May 1978 to
14 July 1978

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N O T E

The work reported here was carried out at the
Institute for Acoustical Research, Miami Div., from
8 March 1978 to 7 July 1978 under ONR Contract Number
N00014-74-C-0229.   "No inventions were conceived or
first put into practice under this contract".

Abstract

This study examines the temporal variation in temperature at several levels from near surface to below the thermocline - a depth of approximately 1900 m. The time series were collected over a 51 day period from 16 February through 6 April 1976 from an area approximately 40 Km northeast of the island of Eleuthera, Bahamas. The study also includes an examination of the temporal and depth changes in the density and Brunt-Väisälä frequency over the period of the record. These changes are discussed in terms of observed changes in the level of activity of the internal tides.

ii

Acknowledgments

iii

Table of Contents

List of Tables

List of Figures

1.0 Introduction and Background for the Data

The temperature data used in the analyses for this study were acquired during February through April 1976 using the BEAR Buoy System. (BEAR - acronymn for Bermuda Eleuthera Acoustics Range). The system comprised a semi-taut surface buoyed mooring system using a thermistor cable to measure ocean temperatures to a depth of approximately 1900 m. The experimental site was located approximately 40 Km northeast of the island of Eleuthera, Bahamas (Fig. 1) at 25° 45'N, 76° 17' W. The anchor position was situated on the abyssal plain approximately 20 Km seaward of the base of the continental slope at a depth of 4797 m. Detailed descriptions can be found in Kronengold (1976), Echternacht (1976), and Echternacht (1977).

The scientific intent of the experiment was to provide data to study the following.

1. To examine the amplitude and relative changes in amplitude of the internal tides along the Eleuthera shelf region.

2. To compare the results of 1. above with open-ocean regions; in particular, the results from MODE and IWEX.

This report presents the following:

1. An examination of temperature time series at varying depths from near surface to below the thermocline. The time series represent a 51 day period from 16 February through 6 April, 1976.
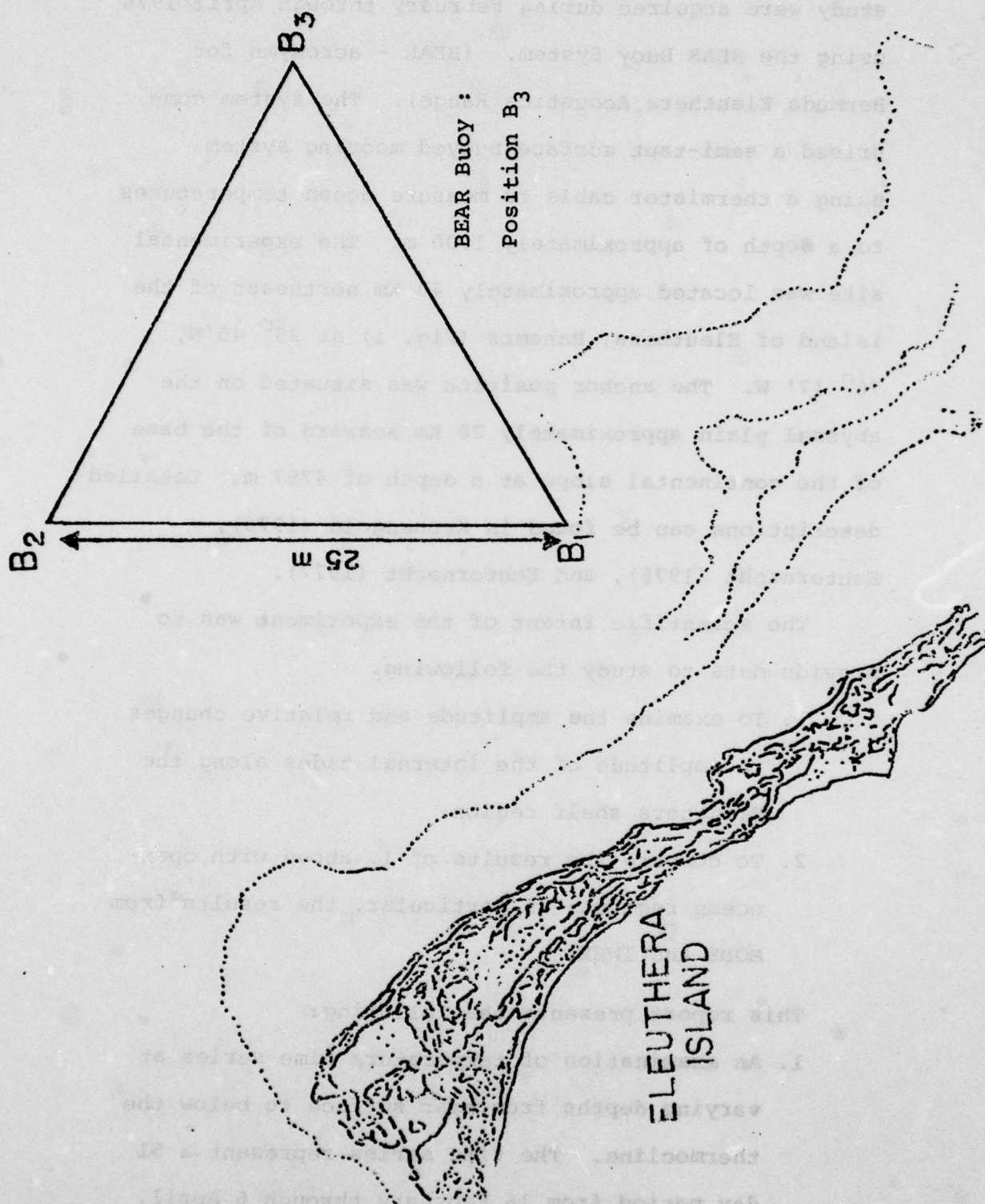
Fig. 1 The Experimental Area

2. An examination of both depth and temporal changes at the high frequency cutoff of the internal wave spectrum - the Brunt Väisälä.

3. A detailed discussion of changes in the internal semi-diurnal tidal field over this period.

4. A qualitative discussion of observed meso-scale features during the period of record.

1.1 The Data Acquisition System

The data were acquired using the BEAR Buoy system. The system, shown schematically in Fig. 2, was comprised of the surface buoy, the thermistor cable, and the nylon and ground tackle sections. The sensor subsystem included the temperature sensors and the mooring sensors.

The temperature sensors (thermistors) were encased in the thermistor cable. The cable, Fig. 2, comprised the upper portion of the mooring and consisted of an inner core of 37 conductors in a wet core configuration. The individual thermistor units were potted and spliced into the cable. The cable, in turn, was protected by a double lay torque balanced steel armor cable. Table 1 lists the nominal depth position of the individual sensor units. Here the nominal depth is defined as the reference sensor depth including mooring line stretch under conditions of zero external forcing.
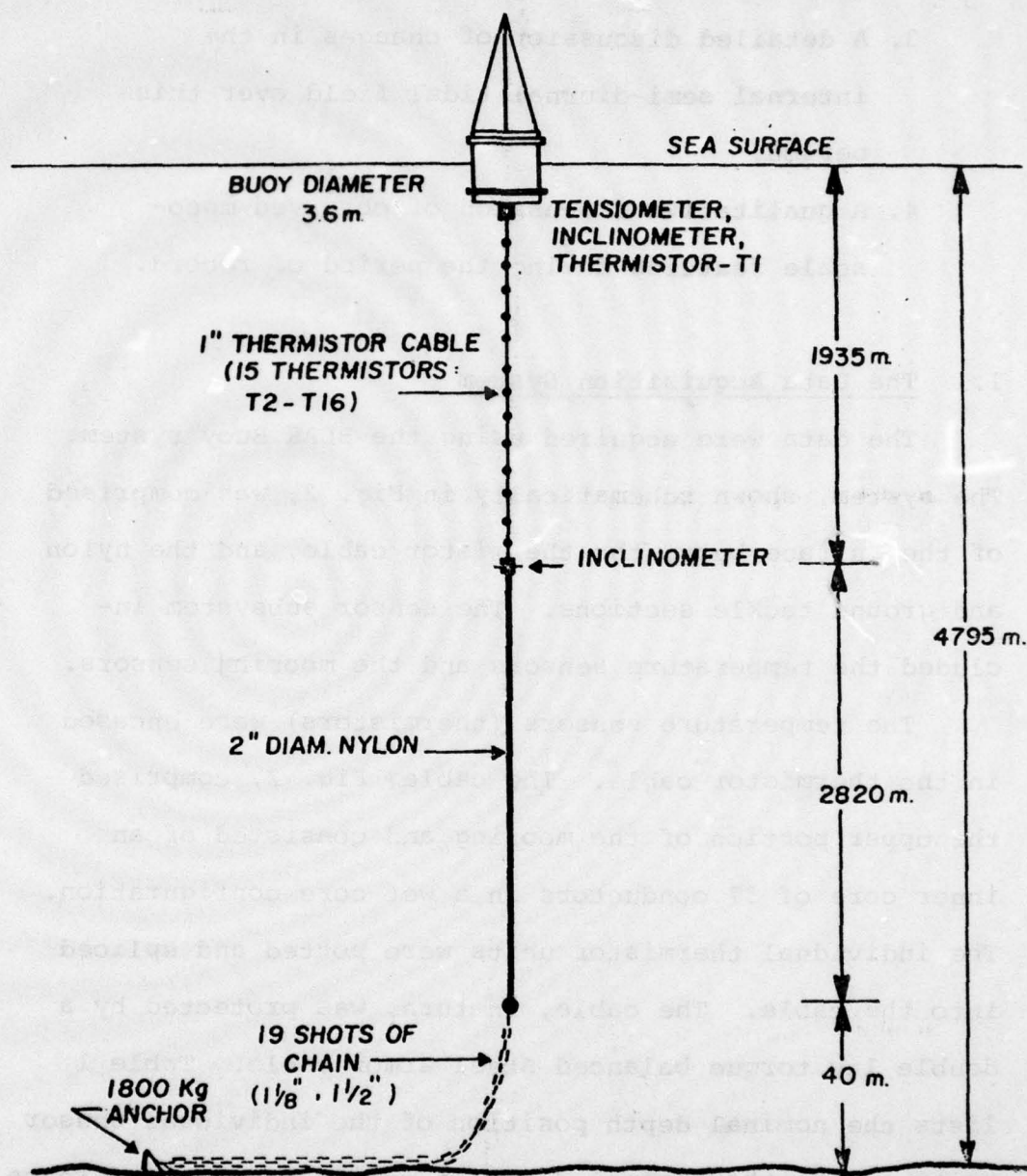
Fig. 2 BEAR BUOY SYSTEM

Sensor No.	Sensor Type	Nominal Depth (m)	Status
1	Thermistor	22.0	
2	"	148.9	non-op
3	"	249.4	
4	"	349.9	
5	"	450.4	
6	"	550.9	
7	"	651.3	
8	"	751.9	
9	"	852.4	
10	"	952.8	
11	"	1053.3	
12	"	1153.8	
13	"	1304.8	Non-op
14	"	1480.4	
15	"	1656.3	
16	"	1832.3	
17	Tensiometer	1.7 *	
18	Inclinometer	21.4	
19	"	1916.0	

*Note: Tensiometer depth measured from the mean waterline –
nominal conditions

Table 1

Nominal Sensor Depth Locations

The mooring sensors included a strain gauge tensio-
meter and two inclinometers. The tensiometer, mounted
in the clevis at the base of the buoy, provided a measure
of the sum of the external forces acting on the mooring
system. The inclinometers were mounted on the thermistor
cable: one near the surface and the other at the lower
end of the thermistor cable ($\sim$1900 m depth). The data
from the mooring sensors provided inputs to an analytical
model which was used to determine the mooring configura-
tion under varying conditions of external forcing.

For a more detailed description of the data acquisi-
tion system the reader is referred to Echternacht (1976).
In that study are included the design specifications
for the buoy system and the component subsystems.

1.2 Methodology Used to Correct the Data Base

Before the temperature data could be used in any
analysis scheme it was necessary to determine sensor
depth locations at each acquisition time. As discussed
in many previous works (eg, Wunsch and Dahlen, 1974)
deep instrumentation located on surface buoyed mooring
lines can undergo vertical excursions as large as several
hundred meters. The large changes in sensor depth result
from low frequency horizontal meanderings of the surface
buoy and changes in configuration of the mooring line
under the action of the surface forces of wind, wave,
and current and subsurface drag due to current.

Given the above, two analytical models were developed. The first was used to study the generalities of mooring configuration changes for varying combinations of the above listed external forces. A second utilizing the same physics computed the environmental forces using explicitly the mooring sensor data. The methodology used in the general model and that used to correct the temperature measurements for vertical displacements are detailed in an earlier report (Echternacht, 1977). The following is a summary of those models.

The mooring configuration model (MCM) was used to analyze the mooring configuration of the BEAR Buoy system for specific case studies of external forcing. The model used explicitly the surface forces acting on the buoy (wind, wave, and current) and subsurface drag on the mooring (due to current) to compute the mooring configuration.

The modified model of the MCM was used to correct the acquired temperature data for bias due to vertical displacements of the thermistor units. The second model, the vertical displacement corrector model (VDCM), used the mooring sensor data to compute the total external surface forcing acting on the buoy and approximated the subsurface drag acting on the mooring.

As discussed in the above referenced report, a comparison of model results (MCM vs VDCM) showed the method used to approximate the subsurface drag to be valid and to yield results consistent with the MCM.

Comparison of VDCM vs XBT measurements showed that
the VDCM reduced the error between buoy acquired and
XBT data by as large as a factor of three for condi-
tions of moderate to strong external forcing.

In application the VDCM was run for each acquisi-
tion time. The model computed the sensor depth for
each sensor location. As detailed in Echternacht (1977)
the temperature signal was corrected for vertical dis-
placement bias by subtracting that portion of the signal
due only to the change in mooring configuration.

2.0   The Temperature Data

The raw temperature and mooring sensors data were
acquired using an interval sampling technique in which
each sensor channel was sampled once at the rate of one
channel per second during the turn-on period. The in-
terval between sampling periods was 12 minutes. The
raw data were converted from the acquired digital units
to engineering units using transfer functions developed
for each sensor. The transfer functions included
specific calibration corrections (refer to Echternacht,
1976). The resulting data set yielded a times series with
occasional data drop-outs. The latter was the result of
equipment malfunctions during the acquisition or telemetry
stages. For purposes of this study a 51.5 day "clean"
section was chosen.

The 51.5 day (12 minute interval) section was then
low-pass filtered yielding time series with the new high
frequency cut off at 3 hours. The temperature data were
then corrected for vertical displacement using the VDCM
as discussed in Section 1.2.

The 3-hourly temperature time series are given in
Fig. 3. The data cover the 51.5 day period from 1200 LST
Julian Day (JD) 46 through JD 97, 1976 (15 February -
6 April). The axes are Julian Days (time) on the abscissa
and temperature (^{O}C) on the ordinate. The same ordinate
scaling was used for all thermistors. The records for
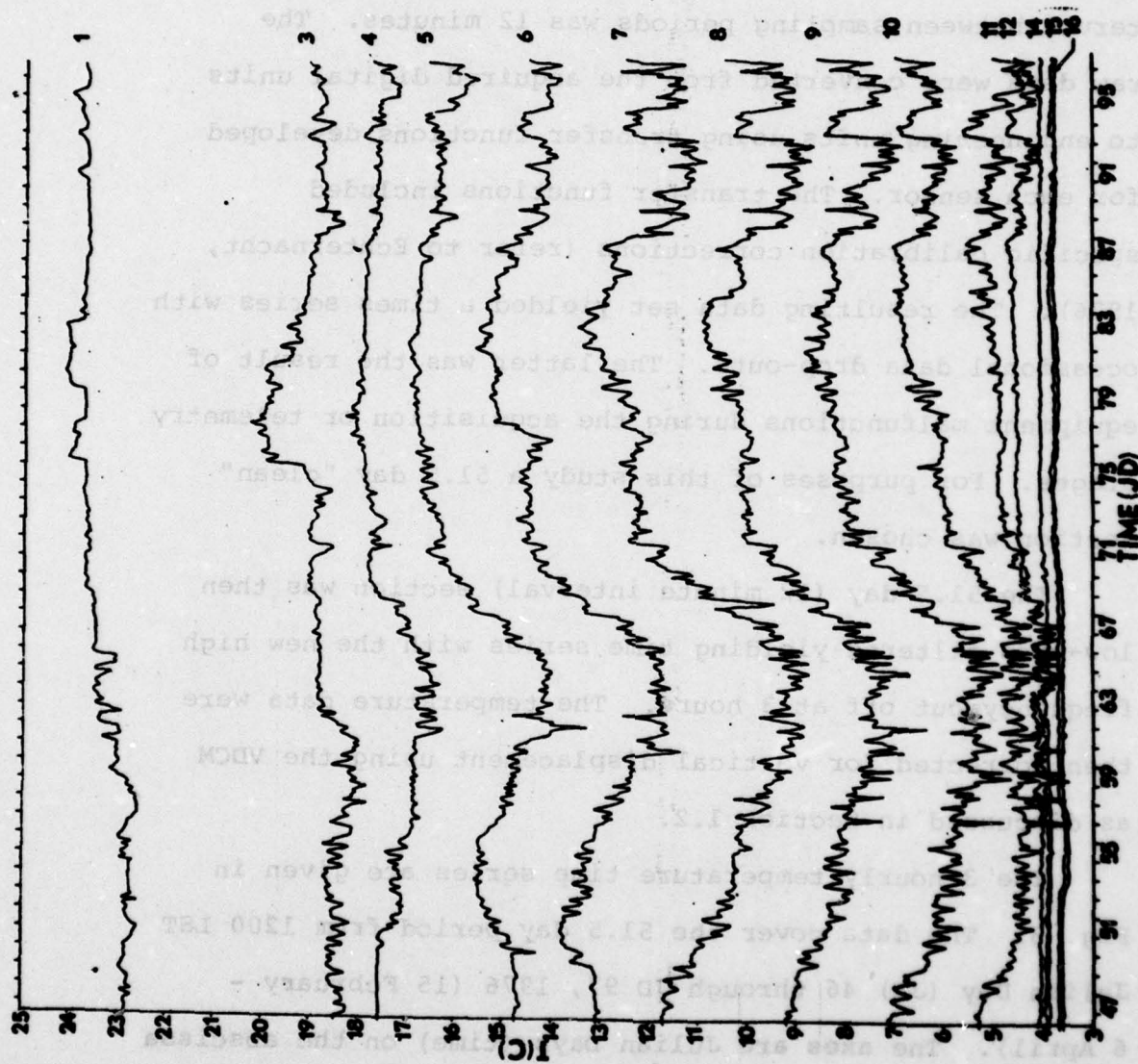
Fig. 3

The BEAR Buoy 3-hourly Temperature Time Series

sensor numbers 2 and 3 are not included - those sensors failed during the system implant. Each temperature trace represents the temperature that occurred at the corrected depth over the period of the record. The sensor numbers and depths appear to the right of each temperature trace. Here the corrected depth refers to the nominal depth as given in Table 1. The obvious features to be noted are the following: (1) a large mesoscale feature covering approximately a 24 day period from the beginning of the record to JD 70, (2) semi-diurnal oscillations. The latter will be discussed later on in this report.

For a first qualitative attempt to classify the mesoscale feature the data were compared with the Ring Criteria defined by Lai and Richardson (1977). In that study they examined changes in isotherm depth location through a cold core cyclonic eddy. Using the 15°C isotherm as an indicator it was noted that in the north-western Sargasso Sea the 15°C location is generally at a depth of 650 m outside an eddy. At the center of the eddy the following features are noted. (1) The 15°C isotherm has been displaced upward by approximately 500 m and (2) packing of the isotherms.

The data given in Fig. 3 were low-pass filtered using a running mean of 4 days and the depth location of selected isotherms plotted for the period of the record.
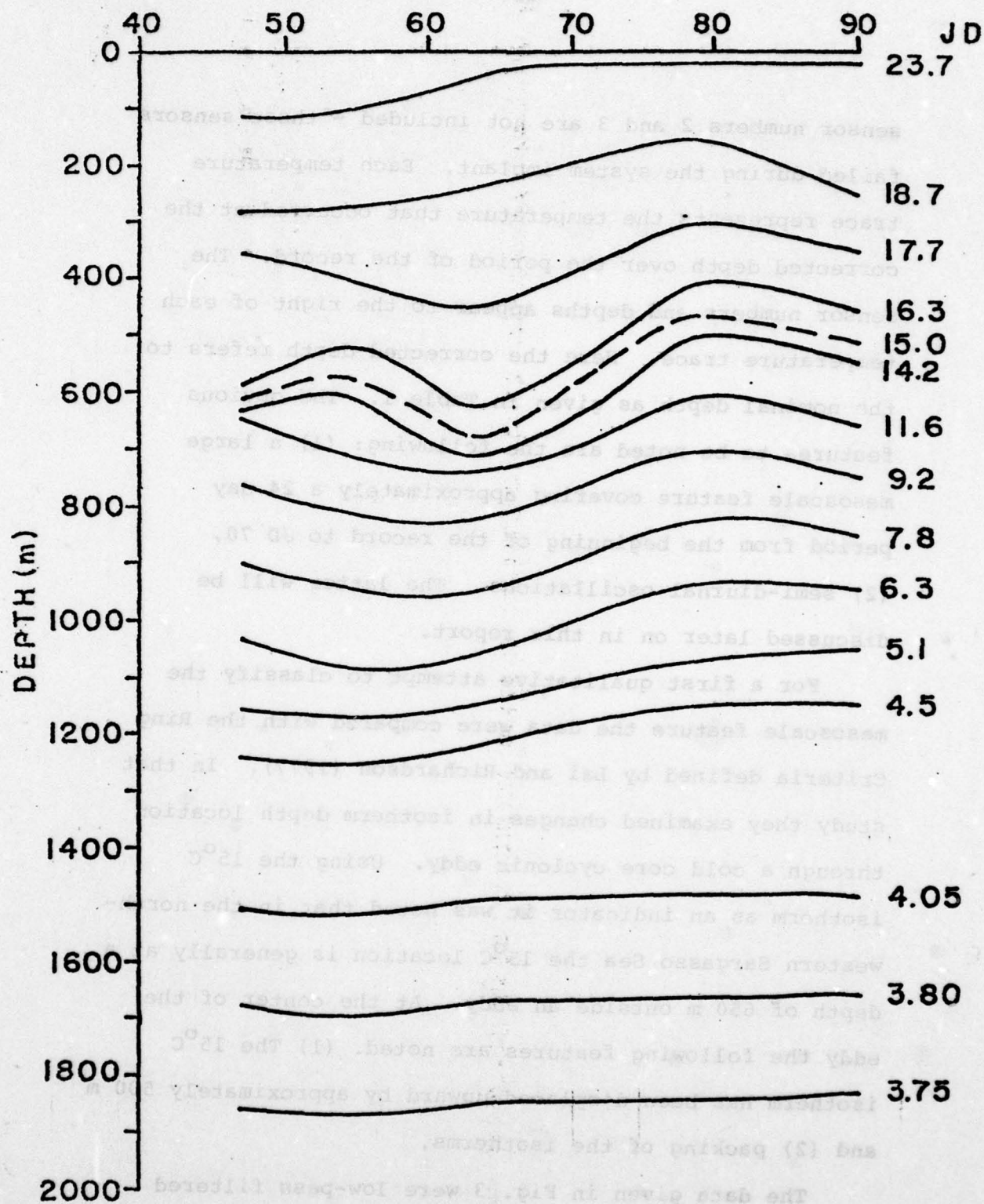
Fig. 4
Isotherm Depth Location

The isotherm locations are given in Fig. 4. As seen in the figure the 15°C isotherm is displaced by approximately 150 m - much less than that observed by Lai and Richardson. Secondly, there is little observable isotherm packing. The data present evidence of a mesoscale event but fail the ring criteria test. However, considering the proximity of the buoy site to the coast ($\sim$40 km) it is obvious that an eddy core would lie well seaward. Thus the only conclusion that can be drawn is that the event might possibly have been the edge of an eddy or meander traversing the study area. The importance of the observation, however, is that mesoscales features are relatively uncommon in the study region (25° 45', 76° 17 W). In the work by Lai and Richardson the number of sighted anomalies were broken down by regions. For the area 30-40 N, 60-80 W there were 948 sightings as compared to 71 for the area bounded by 20-30 N, 65-80 W.

3.0 Data Analyses

In terms of the 3-hourly temperature time series presented in the previous section, the intent of this report is to provide a detailed description of and the changes in the internal semi-diurnal tidal field over the period shown. From an examination of the data given in Fig. 3, the following are noted.

1) Pronounced fluctuations in temperature are evident in the time series; fluctuations of a semi-diurnal periodicity. The semi-diurnal signal appears to be the most energetic.

2) The amplitude of the signal increases with depth to a maximum at approximately 1000 m then decreases with depth through and below the thermocline.

3) Within any given depth zone there exist changes in intensity of the signal with time over the 51.5 day period.

The distribution of energy in the internal wave field is a function of the static stability of the water column. Hence, the analyses to follow examine the spatial and temporal changes in the fields of temperature, density, sound velocity, and static stability.

3.1 Temperature and Salinity

In order to examine the temporal changes in temperature structure the 3-hourly temperature data were low-pass filtered. The filtering consisted of computing three-day means with a

one-day overlap between data sections. The filter was
applied to the temperature data only. As discussed by
Pickard (1964) for warm waters of low latitude origin
changes in the density field are dominated by tempera-
ture not by salinity. Thus for this study the salinity
is considered a conservative property. This assumption
is reasonable considering the length of the record.

The 3-day mean temperature profiles and the mean
salinity profile are given in Fig. 5. The mean salinity
profile was obtained using data from the Fleet Numerical
Weather Center (FNWC). The FNWC data are based on
climatological XBT data for the study region during
the winter months. The temperature and salinity data
are listed in Tables 2 and 3 in the Appendix.

The temperature profiles, in general, are typical of
the winter months for the study area. In comparison to
the summer regime (Mooers, 1975) the shallow warm mixed
layer is absent. However, at the beginning of the record
(profiles 1-6) and during the latter half of the period
(profiles 14-25) there exists a thin layer of decreased
gradient. For profiles 1-6 the change in gradient occurs
over the depth interval of approximately 250 to 550 m and
over the interval of 250 to 650 m for the latter profiles.
In reference to Fig. 4 (page 12) these correspond to the
periods JD 47 through 59 and JD 74 through 97, respectively.
The anomalies are due to the mesoscale feature seen in
Fig. 4.
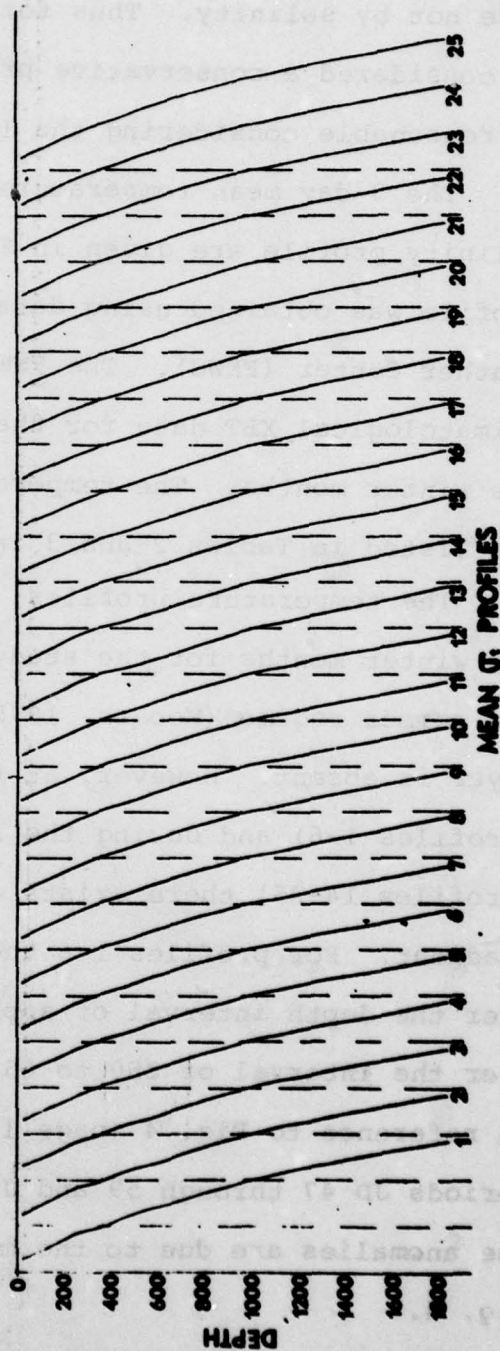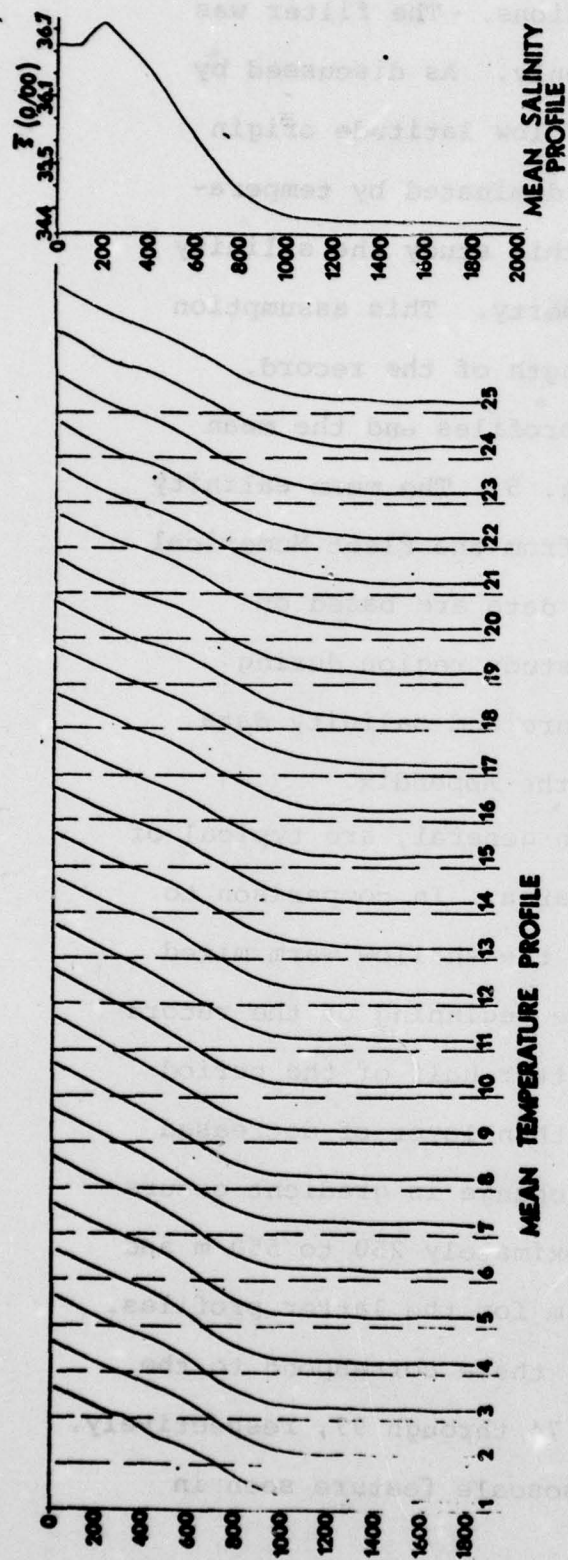
Fig. 5

The salinity profile is typical for those areas influenced by the Antilles Current. The characterizing feature is the subsurface salinity maximum in the region of 100 to 300 m depth.

3.2 The Density Field

The density anomaly, σ_t, was computed using the 3-day mean temperature data, the mean salinity profile, and the corresponding mean sensor depth. The σ_t as used in this study is the in situ density anomaly.

$$\sigma_t = (\rho_{s,t,p} - 1) \times 10^{3} \tag{1}$$

where, the subscript s,t,p indicates in situ.

σ_t profiles were computed for each mean data section. Fig. 5 (bottom) gives the profiles over the period of the record. The σ_t data are listed in Table 4 in the Appendix.

In the case of the σ_t profiles the change in temperature gradient (Fig.5, upper) due to the mesoscale feature results in a noticeable anomaly in σ_t. As will be seen later in the discussion of the static stability these data suggest the possibility of an intrusion of a water mass of different characteristics.

It should be noted that the abscissa scale for Figs. 5 and 6 is a sliding scale. The vertical line separating profiles is the minimum abscissa value for each curve. The scale is given once for each figure in the upper left.

3.3 Sound Speed Profiles

Mean sound speed profiles were computed for each mean data section using the computed mean data (temperature, salinity, and depth). In the software used the pressure is obtained using the mean data listed above. Fig. 6 (bottom) gives the mean sound velocity profiles for each mean section over the 51-day period. The data are listed in Table 5 in the Appendix.

The influence of the mesoscale event is quite evident in the sound speed profiles. The depth level and the amplitude of the sound speed minimum change throughout the period. At the beginning of the record the level of the minimum decreases in depth through approximately profile 6. During the later half of the record the level increases in depth. This strongly suggests first a shallowing followed by a deepening of thermocline depth during the passage of the mesoscale event. This is supported by the results given in Fig. 4. The amplitude of the sound speed minimum increases throughout the period from a value of 1484 ms^{-1} at the beginning of the period to approximately 1488 ms^{-1} at the end after the passage of the mesoscale event.

3.4 Static Stability

Typically the ocean is characterized by stable density
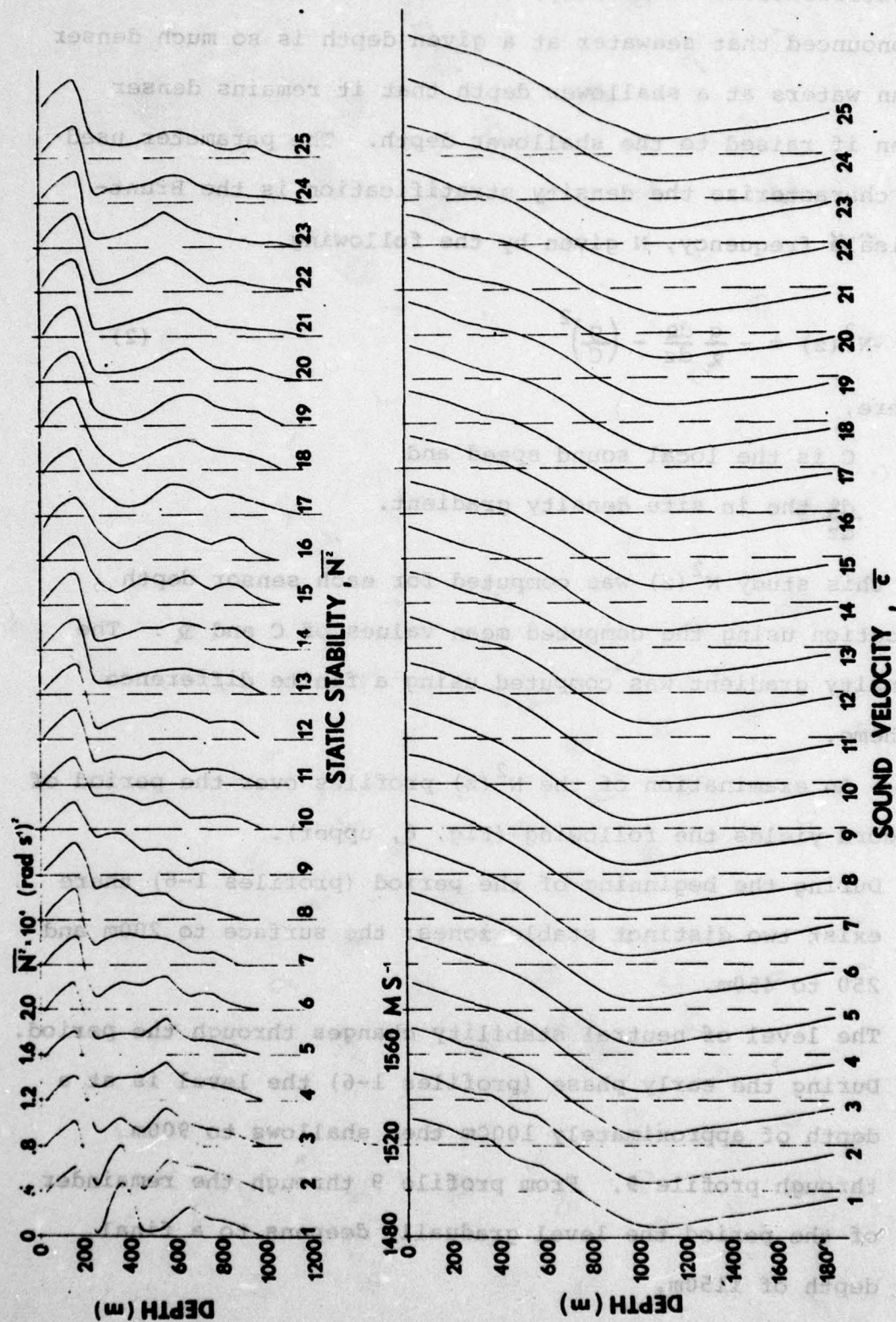
Fig. 6

stratification. Generally, the stratification is so
pronounced that seawater at a given depth is so much denser
than waters at a shallower depth that it remains denser
even if raised to the shallower depth. The parameter used
to characterize the density stratification is the Brunt-
Väisälä frequency, N given by the following.

$$N^2(z) = -\frac{g}{\rho}\frac{d\rho}{dz} - \left(\frac{g}{C}\right)^2 \qquad (2)$$

where,

    C is the local sound speed and

    $\frac{d\rho}{dz}$ the in situ density gradient.

In this study $N^2(z)$ was computed for each sensor depth
location using the computed mean values of C and ρ. The
density gradient was computed using a finite difference
scheme.

    An examination of the $N^2(z)$ profiles over the period of
record yields the following (Fig. 6, upper).

1. During the beginning of the period (profiles 1-6) there
   exist two distinct stable zones: the surface to 200m and
   250 to 450m.

2. The level of neutral stability changes through the period.
   During the early phase (profiles 1-6) the level is at a
   depth of approximately 1000m then shallows to 900m
   through profile 9. From profile 9 through the remainder
   of the period the level gradually deepens to a final
   depth of 1150m.

3. **The latter profiles are more typical of waters influenced
   by the Antilles Current; ie, the stable zone at 100-300m
   depth.**

   These data suggest the presence of two distinct water
masses during the beginning of the period associated with
the passage of the mesoscale feature. This is supported
by the perturbation in the level of neutral stability; ie,
thermocline depth. During the earlier phases the fact
that the deeper stable zone maintained its identity and that
the character of the upper zone did not change appreciably
through the record would suggest that the mesoscale feature
did not have a surface signature of any consequence.

4.0 Discussion and Conclusions

To summarize the analyses presented in this study the following can be concluded.

1. During quiescent periods (i.e., no mesoscale
   transient features present) the temperature,
   density, sound speed, and static stability
   profiles are typical for the study area during
   the winter period. The profiles exhibit the
   influence of the Antilles Current.

2. Over the period of record fluctuations of a semi-
   diurnal periodicity are the dominant feature for
   time scales less than the local inertial. The
   intensity of the semi-diurnal signal, moreover,
   was observed to vary greatly over the 51-day
   period. In terms of the mode structure associated
   with the semi-diurnal wave field the implication
   of the above is that the distribution of energy
   by mode is variable rather than constant as is
   generally assumed for this region.

3. The passage of the transient mesoscale feature
   through the study area perturbed, noticeably, the
   fields of temperature, density, sound speed, and
   static stability - particularly at intermediate
   depths between 300 m and the thermocline. The mode
   shapes (vertical displacements due to the internal
   wave field) are directly proportional to the Brunt-
   Väisälä as given by the following.

$$\frac{d^2 Z_n}{dz^2} + \left(\frac{N^2 - \sigma^2}{\sigma^2 - f^2}\right) \alpha_n^2 Z_n = 0 \qquad (3)$$

where,

Z_n is the vertical displacement,

σ the semi-diurnal tidal frequency,

f the local inertial, and

α the wave number.

Obviously, the solution to Eq. (3) using the N^2 profiles presented in this study would yield a much more complicated picture of the internal wave field for the study area. In particular, the modal structure and distribution of energy by mode changes considerably with time. The importance of these findings to acoustics study for the Bermuda-Eleuthera range is obvious.

Future analyses using the BEAR Buoy data set should examine in detail the modal structure and changes in distribution by mode over the period or record.

REFERENCES

Echternacht, K.L., 1976: BEAR Buoy: The engineering document-
ation for scientific application. IAR Report No. 76002.

_____, 1977: The mooring configuration model and method
used to correct sensors for vertical displacements.
IAR Report No. 77008.

Kronengold, M., 1976: BEAR: An environmental measurement buoy.
Proceedings of the 22nd Internat. Instrumentation
Symposium, San Diego, Cal., May 25-27, 1976.

Lai, D.Y. and P.L. Richardson, 1977: Distribution and
movement of Gulf Stream rings. J. Phys. Oceanogr., 7,
670-683.

Mooers, C.N.K., 1975: Sound-velocity perturbations due to
low-frequency motions in the ocean. J. Acoust. Soc. Am.,
57, 1067-1075.

Pickard, G.L., 1964: Descriptive Physical Oceanography.
Pergamon Press, 199pp.

Wunsch, C. and J.M. Dahlen, 1974: A moored temperature and
pressure recorder. Deep-Sea Res., 21, 145-154.

Appendix:

Data Tables

Profile No.	1		2		3		4		5	
Data No.	T	Z	T	Z	T	Z	T	Z	T	Z
1	22.8	22.0	22.8	22.0	22.8	22.0	22.8	22.1	22.8	22.1
2	20.4	150.0	20.4	150.0	20.4	150.0	20.4	150.0	20.3	150.0
3	18.5	249.6	18.5	249.6	18.5	249.6	18.5	249.6	18.3	249.7
4	17.6	350.2	17.5	350.2	17.2	350.2	17.2	350.2	16.9	350.3
5	14.7	450.7	14.9	450.7	15.3	450.7	15.5	450.7	15.2	450.8
6	13.2	551.3	13.6	551.3	13.5	551.3	13.3	551.3	13.1	551.4
7	11.4	651.8	10.9	651.8	10.5	651.8	10.2	651.9	10.0	652.0
8	8.9	752.4	8.6	752.4	8.2	752.4	8.1	752.4	8.0	752.6
9	6.7	852.9	6.2	852.9	6.0	852.9	5.9	853.0	5.8	853.2
10	5.0	953.5	4.6	953.5	4.4	953.5	4.4	953.5	4.4	953.8
11	4.0	1054.0	4.0	1054.0	4.0	1054.0	4.0	1054.1	4.0	1054.3
12	3.9	1154.6	3.9	1154.6	3.9	1154.6	3.9	1154.7	3.9	1154.9
13	3.9	1481.4	3.9	1481.4	3.9	1481.4	3.8	1481.5	3.8	1481.8
14	3.7	1657.4	3.7	1657.4	3.7	1657.4	3.6	1657.5	3.6	1657.8
15	3.6	1833.4	3.6	1833.3	3.6	1833.9	3.5	1833.4	3.5	1833.9

Table

$\overline{T}$ vs $\overline{Z}$ Profile Data (°C vs m)

(Profiles 1-25)

Profile No.	6		7		8		9		10	
Data No.	T	Z	T	Z	T	Z	T	Z	T	Z
1	22.8	22.1	23.0	22.1	23.3	22.1	23.4	22.1	23.4	22.1
2	20.2	150.0	20.3	150.0	20.6	150.0	20.8	150.0	20.8	150.0
3	18.1	249.8	18.2	249.8	18.5	249.6	18.8	249.9	18.8	250.0
4	16.8	350.5	16.7	350.4	16.6	350.2	16.6	350.5	16.8	350.7
5	14.9	451.1	14.6	451.1	14.2	450.8	14.1	451.2	14.6	451.4
6	12.6	551.8	12.1	551.7	11.9	551.3	11.8	551.8	12.2	552.1
7	9.6	652.4	9.3	652.3	9.2	651.9	9.1	652.5	9.4	652.8
8	7.7	753.0	7.4	752.9	7.3	752.5	7.4	753.1	7.6	753.5
9	5.5	853.7	5.3	853.6	5.4	853.0	5.3	853.8	5.5	854.2
10	4.3	954.3	4.5	954.2	4.5	953.6	4.5	954.4	4.5	954.9
11	4.0	1055.0	4.0	1054.8	4.1	1054.2	4.0	1055.1	4.0	1055.5
12	3.9	1155.6	3.9	1155.4	4.0	1154.7	3.9	1155.7	3.9	1156.2
13	3.8	1482.7	3.9	1482.5	3.9	1481.6	3.9	1482.8	3.9	1483.5
14	3.6	1658.8	3.7	1658.6	3.7	1657.6	3.7	1659.9	3.7	1659.7
15	3.6	1834.9	3.6	1834.6	3.6	1833.5	3.6	1835.1	3.6	1835.9

Table

$\overline{T}$ vs $\overline{Z}$ Profile Data (°C vs m)

(Profiles 1-25)

Profile No. Data No.	11 T	11 Z	12 T	12 Z	13 T	13 Z	14 T	14 Z	15 T	15 Z
1	23.6	22.1	23.7	22.1	23.7	22.0	23.7	22.0	23.8	22.0
2	21.1	150.0	21.1	150.0	21.1	150.0	21.1	150.0	21.4	150.0
3	18.9	249.9	18.9	249.7	18.9	249.6	18.9	249.5	19.6	249.6
4	17.3	350.6	17.7	350.3	17.6	350.1	17.8	350.0	17.9	350.1
5	15.4	451.2	16.1	450.8	16.3	450.7	16.5	450.6	16.6	450.7
6	13.1	551.9	14.0	551.4	14.4	551.2	14.5	551.1	14.4	551.2
7	10.3	652.6	11.5	652.0	12.1	651.7	12.3	651.6	12.3	651.8
8	8.4	753.2	9.2	752.6	9.9	752.3	10.1	752.1	10.0	752.3
9	6.3	853.9	7.1	853.2	7.7	852.8	8.0	852.6	8.1	852.8
10	4.8	954.5	5.3	953.8	5.8	953.4	6.0	953.2	6.1	953.4
11	4.2	1055.2	4.5	1054.3	4.7	1053.9	4.8	1053.7	4.8	1053.9
12	4.1	1155.9	4.4	1154.9	4.5	1154.4	4.5	1154.2	4.5	1154.5
13	3.9	1483.0	4.0	1481.8	4.0	1481.2	4.0	1480.9	4.0	1481.2
14	3.7	1659.2	3.7	1657.8	3.8	1657.1	3.8	1656.8	3.8	1657.2
15	3.6	1835.3	3.7	1833.8	3.7	1833.1	3.8	1832.7	3.7	1833.1

Table

$\overline{T}$ vs $\overline{Z}$ Profile Data ($^{\circ}$C vs m)

(Profiles 1-25)

Profile No.	16		17		18		19		20	
Data No.	T	Z	T	Z	T	Z	T	Z	T	Z
1	23.8	22.1	23.9	22.1	24.0	22.1	23.8	22.1	23.7	22.1
2	21.7	150.0	21.4	150.0	21.5	150.0	21.2	150.0	21.1	150.0
3	20.0	249.9	19.8	249.9	19.5	249.8	19.2	249.7	19.0	249.8
4	18.1	350.5	18.0	350.5	17.9	350.4	17.9	350.3	17.9	350.4
5	16.8	451.1	16.8	451.1	16.9	451.0	16.8	450.9	16.7	451.0
6	14.8	551.8	15.2	551.8	15.3	551.6	15.3	551.5	15.0	551.6
7	12.3	652.4	12.7	652.4	13.1	652.2	13.0	652.1	12.7	652.2
8	10.1	753.0	10.4	753.1	10.7	752.8	10.6	752.7	10.2	752.8
9	8.2	853.7	8.4	853.7	8.5	853.4	8.4	853.2	8.3	853.4
10	6.1	954.3	6.5	954.3	6.7	954.0	6.8	953.8	6.8	954.0
11	4.8	1054.9	4.9	1055.0	5.0	1054.6	5.1	1054.4	5.2	1054.6
12	4.5	1155.6	4.5	1155.6	4.5	1155.2	4.6	1155.0	4.6	1155.3
13	4.0	1482.7	4.0	1482.7	4.0	1482.2	4.0	1481.9	4.1	1482.2
14	3.8	1658.8	3.8	1658.8	3.8	1658.2	3.8	1657.9	3.9	1658.3
15	3.7	1834.9	3.7	1834.9	3.7	1834.3	3.8	1834.0	3.8	1834.4

Table

$\overline{T}$ vs $\overline{Z}$ Profile Data (°C vs m)

(Profiles 1-25)

Profile No.	21		22		23		24		25	
Data No.	T	Z	T	Z	T	Z	T	Z	T	Z
1	23.7	22.1	23.7	22.1	23.7	22.2	23.8	22.2	23.8	22.1
2	21.0	150.0	20.9	150.0	21.0	150.0	21.1	150.0	21.1	150.0
3	18.8	249.7	18.7	249.7	18.8	250.1	18.7	250.2	18.9	250.0
4	17.8	350.3	17.6	350.3	17.7	350.8	17.7	350.9	17.4	350.7
5	16.5	450.9	16.3	451.0	16.3	451.5	16.3	451.7	16.0	451.4
6	14.6	551.5	14.2	551.6	14.2	552.3	14.4	552.5	14.1	552.1
7	12.2	652.1	11.4	652.2	11.3	653.0	11.9	653.2	11.7	652.8
8	9.9	752.7	9.2	752.8	9.2	753.7	9.7	754.0	9.5	753.5
9	8.0	853.3	7.6	853.4	7.4	854.4	7.8	854.7	7.6	854.2
10	6.6	953.9	6.2	954.0	6.1	955.2	6.4	955.5	6.4	954.9
11	5.2	1054.5	5.0	1054.6	5.0	1055.5	5.1	1056.2	4.7	1055.6
12	4.5	1155.1	4.4	1155.2	4.3	1156.6	4.4	1157.0	4.3	1156.3
13	4.1	1482.1	4.0	1482.1	4.0	1484.0	4.0	1484.4	4.0	1483.5
14	3.8	1658.1	3.8	1658.2	3.8	1660.2	3.8	1660.8	3.8	1659.7
15	3.8	1834.2	3.8	1834.2	3.8	1836.5	3.8	1837.1	3.8	1836.0

Table

$\overline{T}$ vs $\overline{Z}$ Profile Data ($^{\circ}$C vs m)

(Profiles 1-25)

30

Data No.	Depth (m)	$\overline{S}$ (o/oo)
1	0	36.54
2	100	36.54
3	200	36.74
4	300	36.55
5	400	36.34
6	500	36.04
7	600	35.75
8	700	35.50
9	800	35.24
10	900	35.14
11	1000	35.03
12	1100	35.02
13	1200	35.02
14	1300	35.01
15	1400	35.01
16	1500	35.01
17	1600	34.99
18	1700	34.98
19	1800	34.97
20	1900	34.96
21	2000	34.95

Table

Mean Salinity Profile Data (o/oo)

Profile No.

Data No.	1	2	3	4	5	6	7	8	9	10
1	25.23	25.23	25.23	25.23	25.23	25.23	25.17	25.08	25.06	25.06
2	26.29	26.29	26.29	26.29	26.32	26.34	26.30	26.22	26.17	26.17
3	27.36	27.36	27.36	27.36	27.41	27.46	27.43	27.36	27.28	27.28
4	27.82	27.85	27.92	27.92	27.99	28.02	28.04	28.07	28.07	28.02
5	28.75	28.70	28.61	28.57	28.64	28.71	28.77	28.86	28.88	28.77
6	29.24	29.16	29.18	29.22	29.26	29.37	29.47	29.51	29.54	29.46
7	29.78	29.88	29.96	30.01	30.05	30.12	30.18	30.19	30.21	30.16
8	30.50	30.55	30.62	30.62	30.65	30.70	30.75	30.76	30.75	30.72
9	31.11	31.19	31.22	31.23	31.25	31.29	31.32	31.30	31.32	31.29
10	31.69	31.74	31.77	31.77	31.77	31.79	31.76	31.76	31.76	31.76
11	32.16	32.16	32.16	32.16	32.16	32.16	32.16	32.14	32.16	32.16
12	32.58	32.58	32.58	32.58	32.58	32.58	32.58	32.57	32.58	32.59
13	33.91	33.91	33.91	33.92	33.92	33.93	33.91	33.91	33.91	33.92
14	34.65	34.65	34.65	34.66	34.66	34.67	34.65	34.65	34.65	34.66
15	35.37	35.37	35.37	35.39	35.39	35.38	35.38	35.37	35.38	35.38

Table

$\overline{\sigma_t}$ Data $(\rho -1) \times 10^3$ (gcm^{-3})

(Profiles 1-25)

Profile
No.

Data No.	11	12	13	14	15	16	17	18	19	20
1	25.00	24.94	24.97	24.97	24.94	24.94	24.91	24.88	24.94	24.97
2	26.12	26.11	26.11	26.11	26.00	25.95	25.96	25.99	26.06	26.10
3	27.25	27.25	27.25	27.25	27.07	26.96	27.02	27.10	27.18	27.23
4	27.90	27.80	27.82	27.77	27.75	27.70	27.72	27.75	27.75	27.75
5	28.59	28.43	28.38	28.33	28.31	28.26	28.26	28.23	28.26	28.28
6	29.27	29.07	28.98	28.96	28.98	28.89	28.80	28.78	28.78	28.85
7	30.00	29.76	29.64	29.60	29.60	29.60	29.52	29.43	29.45	29.52
8	30.58	30.44	30.31	30.28	30.30	30.28	30.22	30.16	30.18	30.26
9	31.18	31.05	30.95	30.90	30.88	30.87	30.83	30.82	30.83	30.85
10	31.72	31.65	31.58	31.54	31.53	31.53	31.47	31.44	31.42	31.42
11	32.14	32.09	32.06	32.05	32.05	32.05	32.04	32.02	32.01	32.00
12	32.56	32.52	32.50	32.50	32.50	32.50	32.50	32.50	32.49	32.49
13	33.92	33.90	33.89	33.89	33.89	33.90	33.90	33.90	33.90	33.88
14	34.66	34.65	34.63	34.63	34.63	34.64	34.64	34.65	34.64	34.62
15	35.38	35.36	35.36	35.34	35.36	35.36	35.36	35.36	35.34	35.35

Table

$\overline{\sigma}_t$ Data $(R-1) \times 10^3$ (gcm^{-3})

(Profiles 1-25)

Profile No. Data No.	21	22	23	24	25
1	24.97	24.97	24.97	24.94	24.94
2	26.12	26.14	26.12	26.11	26.10
3	27.28	27.30	27.28	27.28	27.26
4	27.77	27.82	27.80	27.80	27.87
5	28.33	28.38	28.38	28.38	28.45
6	28.94	29.03	29.03	28.99	29.05
7	29.62	29.78	29.80	29.69	29.72
8	30.32	30.44	30.45	30.36	30.39
9	30.90	30.97	31.00	30.94	30.97
10	31.46	31.52	31.54	31.49	31.49
11	32.00	32.02	32.03	32.02	32.07
12	32.50	32.52	32.54	32.52	32.53
13	33.88	33.90	33.90	33.91	33.90
14	34.64	34.64	34.64	34.65	34.64
15	35.35	35.35	35.36	35.36	35.35

Table
$\overline{\sigma}_t$ Data $(R-1) \times 10^3$ (gcm^{-3})

(Profiles 1-25)

Profile No. Data No.	1	2	3	4	5	6	7	8	9	10
1	1531.6	1531.6	1531.6	1531.6	1531.6	1531.6	1532.0	1532.8	1533.0	1533.0
2	1527.8	1527.7	1527.7	1527.7	1527.5	1527.2	1527.6	1528.4	1528.9	1528.9
3	1523.9	1523.9	1523.9	1523.9	1523.4	1522.8	1523.1	1523.9	1524.8	1524.9
4	1522.8	1522.5	1521.6	1521.6	1520.7	1520.4	1520.1	1519.8	1519.8	1520.4
5	1515.3	1515.9	1517.2	1517.8	1516.9	1515.9	1515.0	1513.7	1513.4	1515.0
6	1511.7	1513.0	1512.7	1512.0	1511.4	1509.7	1508.0	1507.3	1507.0	1508.3
7	1506.8	1505.1	1503.6	1502.6	1501.9	1500.4	1499.3	1498.9	1498.6	1500.0
8	1499.2	1498.1	1496.2	1496.2	1495.8	1494.7	1493.5	1493.1	1493.5	1494.3
9	1492.2	1490.2	1489.0	1489.4	1488.6	1487.4	1486.6	1487.0	1486.6	1487.4
10	1486.9	1485.2	1484.4	1484.4	1484.4	1484.0	1484.8	1484.8	1484.8	1484.8
11	1484.3	1484.3	1484.3	1484.3	1484.3	1484.3	1484.3	1484.7	1484.3	1484.3
12	1485.5	1485.5	1485.5	1485.5	1485.5	1485.6	1485.6	1486.0	1485.6	1485.6
13	1491.0	1491.0	1491.0	1490.6	1490.6	1490.6	1491.0	1491.0	1491.0	1491.0
14	1493.1	1493.1	1493.3	1492.7	1492.7	1492.7	1493.2	1493.2	1493.2	1493.2
15	1495.7	1495.7	1495.7	1495.3	1495.3	1495.7	1495.7	1495.7	1495.7	1495.7

Table

$\bar{C}$ Data (ms^{-1})

(Profiles 1-25)

Profile
No.

Data No	11	12	13	14	15	16	17	18	19	20
1	1533.5	1533.8	1533.8	1533.8	1534.0	1534.0	1534.2	1534.5	1534.0	1533.8
2	1529.3	1529.4	1529.4	1529.4	1530.5	1531.1	1530.9	1530.6	1530.0	1529.6
3	1525.1	1525.1	1525.1	1525.1	1527.0	1528.1	1527.6	1526.7	1525.9	1525.4
4	1521.9	1523.0	1522.8	1523.3	1523.6	1524.2	1523.9	1523.6	1523.6	1523.6
5	1517.5	1519.7	1520.3	1520.9	1521.2	1521.8	1521.8	1522.1	1521.8	1521.5
6	1511.4	1514.3	1515.6	1515.9	1515.6	1516.9	1518.2	1518.5	1518.5	1517.5
7	1503.0	1507.2	1509.3	1509.9	1509.9	1510.0	1511.3	1512.6	1512.3	1511.3
8	1497.3	1500.3	1502.9	1503.6	1503.2	1503.6	1504.7	1505.8	1505.4	1504.0
9	1490.6	1493.7	1496.1	1497.2	1497.6	1498.0	1498.7	1499.1	1498.7	1498.4
10	1486.1	1488.1	1490.1	1490.9	1491.3	1491.3	1492.9	1493.7	1494.1	1494.1
11	1485.1	1486.4	1487.2	1487.6	1487.6	1487.6	1488.0	1488.4	1488.8	1489.2
12	1486.4	1487.6	1488.0	1488.0	1488.0	1488.0	1488.0	1488.0	1488.4	1488.5
13	1491.0	1491.4	1491.4	1491.4	1491.4	1491.4	1491.4	1491.4	1491.4	1491.9
14	1493.2	1493.1	1493.6	1493.6	1493.6	1493.6	1493.6	1493.6	1493.6	1494.0
15	1495.7	1496.1	1496.1	1496.5	1496.1	1496.1	1496.1	1496.1	1496.5	1496.5

Table

$\bar{C}$ Data (ms^{-1})
(Profiles 1-25)

Profile No.	21	22	23	24	25
Data No.					
1	1533.8	1533.8	1533.8	1534.0	1534.0
2	1529.3	1529.1	1529.3	1529.4	1529.5
3	1524.8	1524.5	1524.8	1524.8	1525.1
4	1523.3	1522.8	1523.0	1523.0	1522.2
5	1520.9	1520.3	1520.3	1520.3	1519.4
6	1516.3	1515.0	1515.0	1515.6	1514.7
7	1509.6	1507.8	1506.5	1508.6	1507.9
8	1502.9	1500.3	1500.3	1502.2	1501.4
9	1497.2	1495.7	1494.9	1496.5	1495.7
10	1493.3	1491.7	1491.4	1492.6	1492.5
11	1489.2	1488.4	1488.4	1488.9	1487.2
12	1488.0	1487.6	1487.2	1487.7	1487.2
13	1491.9	1491.4	1491.5	1491.5	1491.5
14	1493.6	1493.6	1493.6	1493.6	1493.6
15	1496.5	1496.5	1496.6	1496.6	1496.6

Table

$\overline{C}$ Data (ms^{-1})

(Profiles 1-25)

Profile No.	1	2	3	4	5	6	7	8	9	10
1	3.84	3.84	3.84	3.84	4.04	4.22	4.35	4.39	4.22	4.22
2	6.07	6.07	6.07	6.07	6.30	6.53	6.69	6.77	6.52	6.51
3	0.28	0.51	1.21	1.21	1.42	1.17	1.64	2.59	3.33	2.87
4	4.65	3.98	2.41	1.97	1.93	2.34	2.75	3.37	3.57	2.98
5	0.50	0.12	1.19	2.04	1.78	2.12	2.45	1.98	1.96	2.25
6	0.88	2.63	3.15	3.27	3.21	2.90	2.43	2.21	2.18	2.45
7	2.52	2.08	1.99	1.61	1.42	1.18	1.13	1.11	0.79	0.99
8	1.53	1.76	1.38	1.36	1.34	1.27	1.07	0.78	1.07	1.11
9	1.17	0.95	0.92	0.78	0.64	0.35				0.10
10	0.07									
11										
12										
13										
14										
15										

*Note: Blanks indicate the data approach 0.0

Table

Static Stability $N^2 \times 10^4$ $(rad/sec)^2$

(Profiles 1-25)

Profile No.									
Data No.	11	12	13	14	15	16	17	18	19	20
1	4.35	4.46	4.45	4.45	3.88	3.49	3.80	4.21	4.28	4.36
2	6.68	6.84	6.85	6.86	6.12	5.59	5.98	6.51	6.61	6.70
3	1.96	1.02	1.26	0.79	2.30	2.83	2.56	2.04	1.29	0.79
4	2.42	1.82	1.13	1.15	1.16	1.18	0.94	0.47	0.70	0.93
5	2.22	1.95	1.56	1.81	2.25	1.86	0.99	1.01	0.77	1.20
6	2.68	2.35	2.05	1.88	1.66	2.52	2.61	2.03	2.23	2.17
7	1.31	2.21	2.16	2.20	2.38	2.20	2.45	2.72	2.70	2.81
8	1.28	1.44	1.75	1.63	1.29	1.30	1.52	1.91	1.89	1.32
9	0.84	1.38	1.56	1.82	1.84	2.00	1.76	1.62	1.31	1.14
10			0.33	0.44	0.58	0.58	1.04	1.21	1.22	1.09
11							0.43	0.18	0.18	0.32

Table I. Static Stability $N^2 \times 10^4 (rad/sec)^2$

(Profiles 1-25)

*Note: Blanks indicate the data approach 0.0

Profile No.	21	22	23	24	25
Data No.					
1	4.55	4.65	4.56	4.68	4.57
2	6.96	7.08	6.92	7.05	6.95
3	0.54	0.76	0.77	0.77	1.73
4	1.15	1.13	1.36	1.36	1.33
5	1.59	1.98	1.98	1.56	1.51
6	2.28	2.96	3.14	2.43	2.18
7	2.36	2.02	1.83	2.11	2.08
8	1.27	0.68	0.99	1.23	1.20
9	0.95	0.90	0.73	0.92	0.61
10	0.78	0.46	0.32	0.62	1.15
11	0.45	0.31	0.44	0.44	0.03
12					
13					
14					
15					

*Note: Blanks indicate the data approach 0.0

Table

Static Stability $N^2 \times 10^4$ $(rad/sec)^2$

(Profiles 1-25)

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
IAR-78001		

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
BEAR BUOY: Analyses of Acquired Temperature Data	Final Report, July 1976
	6. PERFORMING ORG. REPORT NUMBER
	8 Mar - 7 Jul. 78

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
Kenneth L. Echternacht	N00014-74-C-0229

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Institute for Acoustical Research 615 S.W. 2nd Ave. Miami, Fla. 33130	

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Procuring Contracting Officer Office of Naval Research, Dept. of the Navy, Arlington, Va. 22217	July 1978
	13. NUMBER OF PAGES
	51

14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)	15. SECURITY CLASS. (of this report)
Office of Naval Research Resident Rep. Columbia University Lamont Doherty Geological Observatory Torrey Cliff, Palisades, N.Y. 10913	Unclassified
	13a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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54 p.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Buoy measurements
Temperature profiles
Static stability profiles
Sound velocity profiles
Density profiles

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study examines the temporal variation in temperature at several levels from near surface to below the thermocline - a depth of approximately 1900 m. The time series were collected over a 51 day period from 16 February through 6 April 1976 from an area approximately 40 Km northeast of the island of Eleuthera, Bahamas. The study also includes an examination of the temporal and depth changes

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in the density and Brunt-Vaisala frequency over the period
of the record. These changes are discussed in terms of
observed changes in the level of activity of the internal
tides.